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HAZARDS ANALYSIS OF LARGE CALIBER MUNITIONS METAL PARTS PLANTS

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US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
LARGE CALIBER
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This analysis was directed toward prevention of equipment failures. Six typical metal parts plants were surveyed to determine if hazards exist in the industrial process equipment and, if so, to determine what can be done to avoid future problems. Results show several areas within the plants which are in need of remedial action. Recommendations are made in the areas of equipment specification, installation, operation, and maintenance.

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INTRODUCTION

Study Objectives

The Munitions Production Base Modernization and Expansion Program has in the past several years resulted in the installation of new and rebuilt equipment in a number of plants. This effort will be continuing in the future. There have been several instances in which recently installed equipment has failed, resulting in property damage and loss of productive capacity. This study was aimed at determining if hazards exist in the industrial process equipment and if so, what can be done to avoid future problems. Attention was confined to six typical plants producing metal parts for large caliber munitions. A team comprised of government and contractor personnel surveyed each of the six plants and recorded their observations. This information was analyzed and the resulting conclusions indicated several areas within the plants which are in need of remedial action. Recommendations are made in the areas of equipment specification, installation, operation and maintenance.

Relationship to Safety

The emphasis of the study was directed toward prevention of equipment failures rather than assuring the safety of personnel. It is obvious that prevention of major equipment damage and/or failures will contribute directly or indirectly to personnel safety, but it must also be recognized that perfect, failure-free, plant equipment will not assure the safety of plant personnel. It is noted by Heinrich* that accidents involving people in an industrial environment normally will have a distribution of approximately 10% caused by machinery;

*H. W. Heinrich, Industrial Accident Prevention, 4th ed., McGraw-Hill Book Co., Inc., 1959.

2% due to acts of God such as floods, power failure, storms, etc.; and 88% people caused (induced). Heinrich also concludes that 98% of all accidents are of a preventable type and that 50% of those are preventable. However, personnel safety is the main concern of the Occupational Safety and Health Act. It is assumed that all equipment will be purchased, installed, tooled, and operated in such a manner as to be in compliance with OSHA standards.

Basis for Conclusions and Recommendations

Because of the military application of the products produced by the plants, there is the possibility that equipment failures should be considered as intolerable and that production must be uninterruptable at whatever the cost. This viewpoint would result in a set of manufacturing facility guidelines based on 100% reliability criteria. No known equipment is 100% reliable and to approach 100% reliability results in prohibitive costs. Therefore, a reasonable approach to the problem is to settle for something less than 100% failure free performance and to accept reasonable risks. Adoption of this viewpoint results in a set of guidelines based on economics. This latter viewpoint was used as the basis for the conclusions drawn and recommendations made in this study.

Procedure for Plant Surveys

Prior to starting the plant surveys a Hazard Questionnaire was developed (app A). This questionnaire was designed to obtain information from the plants which would be helpful in determining what equipment hazards exist and what could be done to abate them. An Observation Guide for Hazards Analysis was also assembled as an aid in making the surveys. This was further supplemented by an Operating Practices Check-List. The procedure for a plant survey was as follows:

First Day

1. Upon arriving at a plant in the morning, an hour or two was spent with local plant personnel. During this time, the nature of the mission was reviewed and the plant representative(s) were asked for a general overview of the operation including process flow and equipment.
2. The balance of the day was spent in making a survey of the facility generally following process flow through the plant. Observations and notes were made during the tour.
3. In the evening, observations made during the day were reviewed. Areas which required further inspection were noted.

Second Day

1. Notes taken the day before were discussed with the plant representatives.
2. A spot check was made of those locations noted previously as requiring further inspection.
3. Following the spot checks, a wrap-up session was conducted with the plant personnel. This meeting was a question-and-answer session in an effort to acquire additional information regarding the plant and its equipment. During the meeting the Hazard Questionnaire was reviewed and a copy was left behind to be filled out and sent to ARRADCOM. These questionnaires were to be used in preparation of this report since they could reveal problems not previously observed and could also be corroborative of some problems noted.

Post Visit

Following each visit, the major findings were noted. These findings were used collectively to identify the areas requiring improvement and to form the substance of this report. The responses to the Hazard Questionnaires were reviewed and their substance was incorporated in this report.

METHODOLOGY FOR STUDY

Available Techniques

Fault tree analysis (FTA) is one of the methods of systems safety analysis. It is a detailed deductive analysis which requires in-depth system information. It may be used to identify potential accidents in a system design and to predict the most likely causes of system failure in the event of a system breakdown. Fault tree analysis is started by identifying undesired events by inductive analysis, such as a preliminary hazard analysis or by intuition. The fault tree is structured with sequences of events which lead to the top undesired event.

Another tool or technique useful in hazard analysis is the Failure Mode and Effects Analysis (FMEA) which is similar to FTA. Application of this technique requires a detailed list of the component parts and subsystems which make up a system. In contrast to FTA, analysis is started at the component level at the bottom and continues to the system level where the effects of failure of the system are analyzed. Use of FMEA and FTA has been spurred by record numbers of product liability suits and increasing size of awards. For this reason, both the FTA and the FMEA have found a major application in investigating new designs before actually placing the product on the market. They are also applied to analyze systems whose failure would have serious economic and safety consequences. The aerospace, chemical, and nuclear industries are prime examples. Both of these techniques could be used to analyze the pieces of equipment and integrated systems in a metal parts plant manufacturing large caliber projectiles and cartridge cases. This task would be quite sizable and time consuming and could best be performed by the equipment and/or system manufacturer. Because of the cost and time considerations, as well as the fact that the equipment being used is of off-the-shelf type with known characteristics, the FTA and FMEA were not considered for this study. Instead, a technique using in-plant observations by a team composed of government and contractor personnel was used. This technique usually results in a study adequate for most purposes but certainly is less rigorous than a complete FTA or FMEA analysis. The nature of the metal parts manufacturing plants is such that the need to approach a no-risk (zero risk) status is not evident from a benefits or economic feasibility standpoint since this is prohibitively expensive. Significant failures of equipment in metal parts producing plants usually result in an interruption of production, but rarely endanger human life.

EQUIPMENT PROVE-OUT

One of the unique facets of the Munitions Production Base Modernization and Expansion Program is that it results directly in the purchase and acquisition of production equipment which may not be used in the immediate future. Thern are many supportive reasons for this - not the least of which is that in time of need there may be no time to acquire, install and operate the required equipment. However, purchase, installation and layaway of manufacturing equipment is not characteristic of private industry and therefore has little history except in the military application associated with it. The acceptance evaluation technique currently being used in the plants inspected is normal in that provision is made for each piece of equipment to be proven out by producing a small quantity of parts in order to verify cycle time, accuracy and performance. In private industry, acceptance would then be followed by starting regular production and the equipment would receive normal use. Equipment failures, breakdowns, and pecularities would be uncovered and corrected within the warranty period. In the case of the newly acquired equipment put into layaway this will not happen. Defects may not be revealed in the brief acceptance test period.

The cost of operation for one year with no need for the metal parts may be prohibitive, but in the case of duplicate pieces of equipment, a better answer may be available than is currently being used. Instead of running 15,000 pieces in each of 5 duplicate lathes, it may be more productive to run 75,000 pieces on one machine. Any machine deficiencies which are revealed may be corrected within the warranty period and the same corrections applied to the other 4 machines. Requirements for tooling changes may also be revealed in this manner more easily and the same changes made for the other machines.

The attempt to be made in following this procedure is to get past the infant mortality stage and shake out other problems which always seem to exist. The degree to which operating problems exist will usually depend on how new and innovative the pieces of equipment are and how much preshipment production was run at the vendor's plant. Standard, fully developed tools such as presses or lathes may of themselves require little prove-out, but the automatic loading and unloading systems may be quite new and consequently be trouble prone. Difficulty may be either mechanical, electrical or both. Interface between the controls for the handling equipment and the press, lathe or other tool may not be adequately designed. For example, a short run for prove-out may not reveal the lack of interlocks. These may show up several years later when the equipment is started up for a longer production run and all (or most of) the equipment is operated simultaneously. Unfortunately, the warranty period will probably have expired.

PLANTS SURVEYED

Status, production volume, and characteristics of plants visited are shown in tables 1 and 2.

Observations at Plants

Observations made at the plants (on file at ARRADCOM), are summarized below.

Forge Press Area

Forge Press Type

Hydraulic - 5 plants

Mechanical - 2 plants

Forge Press Hydraulic Fluid

Fire Resistant - 3 plants

Conventional - 3 plants

Forge Press Cleaning Schedule

Regular - 1 plant

Irregular - 5 plants

Forge Lubricant

Combustible - 4 plants

Water Base - 2 plants

Heat For Forge

Furnace Types Used

Rotary Hearth - 4 plants

Roller Hearth - 1 plant

Induction - 3 plants

Hydraulic Loading Device Fluid

Fire Resistant - 3 plants

Conventional - 1 plant

Not Used - 2 plants

Table 1. Status and production volume of plants surveyed

Plant	Date of Visit	Status of Modernization/Expansion	Production Volume
Scranton AAP Scranton, PA	24, 25 Jan. 1978	Modernization & expansion partially complete. New product expansion preliminary.	Small
Louisiana AAP Shreveport, LA	31 Jan., 1 Feb. 1978	Modernization & expansion partially complete.	None
National Presto Ind. EauClaire, WI	14, 15 Feb. 1978	Modernization & expansion partially complete.	Very small
Norris Industries Vernon, CA	27, 28 Feb. 1978	Modernization & expansion partially complete. New product expansion preliminary.	Many different products
Riverbank AAP Riverbank, CA	1,2 Mar. 1978	Modernization & expansion partially complete. New product expansion partially complete.	None
Chamberlair Corp. New Bedford, MA	7 Mar. 1978	Modernization & expansion - none at this time.	Small

Table 2. Characteristics of plants surveyed

Plant	Type	Original Purpose	Total Site Size (acres)	Buildings	Plant Area (sq ft)	Process
Scranton AAP Scranton, PA	GOCO	Railroad Maintenance	15.3	Multiple	351,000	Hot Forge - Heat Treat
Louisiana AAP Shreveport, LA	GOCO	Projectiles	14,974	Single	325,000	Hot Forge - Heat Treat
National Presto Ind. EauClaire, WI	COCO	Small Appliances	340	Single	366,000	Hot Cup - Cold Draw
Norris Industries Vernon, CA	COCO	Misc. Metal Parts	N.A.	Multiple	1,000,000	Hot Forge - Heat Treat Cold Forming
Riverbank AAP Riverbank, CA	GOCO	Aluminum Reduction	172	Multiple	736,000	Hot Forge - Heat Treat Cold Forming
Chamberlain Corp. New Bedford, MA	COCO	Fabric Mill	10.7	Single	561,000	Hot Forge - Heat Treat

Special Atmosphere

Yes - 3 plants

No - 3 plants

Heat Treat

Furnace Types Used

Roller Hearth - 4 plants

Box Type - 1 plant

Salt Bath - 2 plants

Stress Relieve - 2 plants

Furnace Location

Separate Building - 2 plants

With Other Equipment - 4 plants

Special Control Room

Yes - 3 plants

No - 3 plants

Fuel Used

Gas - 5 plants

Dual - 1 plant

Fires in Quench Area

Yes - 4 plants

Special Atmosphere

Yes - 5 plants

Not Used - 1 plant

Computerized Controls

Yes - 1 plant

No - 4 plants

Not Used - 1 plant

Building & Systems

Construction Materials

Steel & Masonry - 4 plants

Some Wood - 2 plants

Mult. Level - Mfg. Area

Yes - 2 plants

No - 4 plants

Electrical Distribution System

Good - 4 plants

Questionable - 2 plants

Emergency Power

Yes - 2 plants

No - 4 plants

Built For Projectiles

Yes - 1 plant

No - 5 plants

Roof Leaks

Yes - 2 plants

Unknown - 4 plants

Alternate Fuel Source

Yes - 4 plants

No - 2 plants

Propane Storage

Yes - 4 plants

No - 2 plants

Lightning Protection - Propane Storage

Yes - 3 plants

No - 1 plant

Not Used - 2 plants

Fire Protection

Sprinkler Systems Coverage

Complete - 4 plants

Partial - 2 plants

Municipal Coverage

Yes - 4 plants

No - 2 plants

Special Systems

Yes - 3 plants

No - 3 plants

Own Fire Trucks

Yes - 2 plants

No - 4 plants

Training/Safe Operating Procedures

Yes - 1 plant

No - 5 plants

Maintenance Training Programs

Yes - 1 plant

Unknown - 5 plants

Processes & Equipment

During visits to the plants a record of the process used and the equipment employed was made. The types of equipment found are listed below, with a general description. The costs given are in FY78 dollars and are based on vendor estimates for similar equipment, including normal installation.

Process Equipment	Cost ($K)
Heating	
Rotary hearth furnace with atmos.	1,000
Roller hearth furnace with atmos.	1,700
Induction heating	500
Batch furnace with atmos.	200
Roller type tempering furnace	500
Controlled cooling tunnel	500
Salt bath	700
Dry-off oven	100
Baking oven (paint or fiberglass wrap)	150
Metal Forming	
Hydraulic press	1,200
Mechanical press	1,200
Special presses	300
Metal Removal	
Automatic lathes	150
N.C. lathes	200
Tracer lathes	105
Chuckers	150
Special boring	200
Threaders	120
Grinders	180
E.C.M.	100
Keyway slotters	90
Finishing	
Shot blast	80
Pickle & phosphate	375

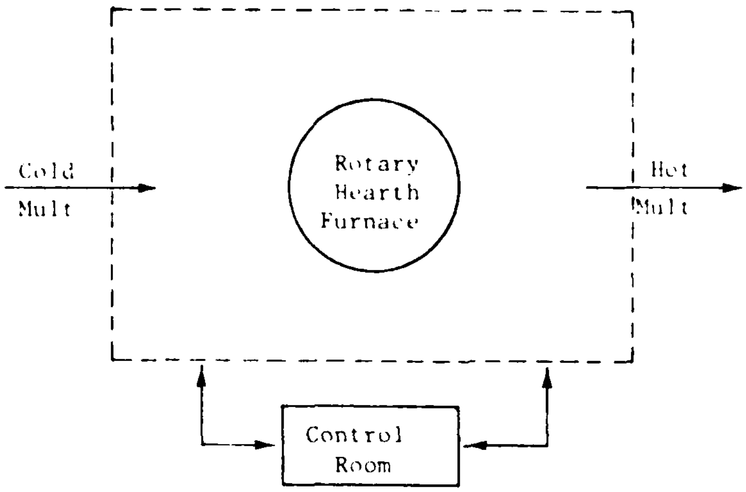
	Cost ($K)
Soap coat	100
Electro clean	200
Degreasing	175
Spray wash	150
Immersion wash	220
Water descaling	120
Electrostatic painting	60
<u>Welding</u>	
MIG - special	100
Plasma - special	110
Resistance	75
TIG	20
Carbon arc gouging	15
<u>Material Handling</u>	
Bridge crane	210
Gantry crane	225
Boom crane	100
Jib crane	15
Fork lift truck	25
Live roll conveyor	50
Belt conveyor	30
Chip conveyor system	125
Overhead chain conveyor	90

High Risk/Value Processes

Three processes were selected for further study. These processes were heat for forge, forge, and heat treat. These three processes were also confirmed as possible high risk areas by ovservations made during the plant surveys. Consideration was given to (1) high replacement cost, (2) the risk of loss due to the inherent nature of the equipment, and (3) the typical working environment in the plants. A brief analysis of each is shown below.

Rotary Hearth Furnace

The following diagram is the Block Level representation for a rotary hearth furnace.



Block Level Events which may cause failure or loss of function:

1. Loss of electrical power
2. Loss of fuel supply
3. Loss of cooling water
4. Internal mechanical failure
5. Loading/unloading mechanism failure
6. Explosion/fire
7. Operator error
8. Loss of control
9. Act of God (external fire, flood, wind, earthquake)
10. Sabotage, war-bomb, missile, etc.

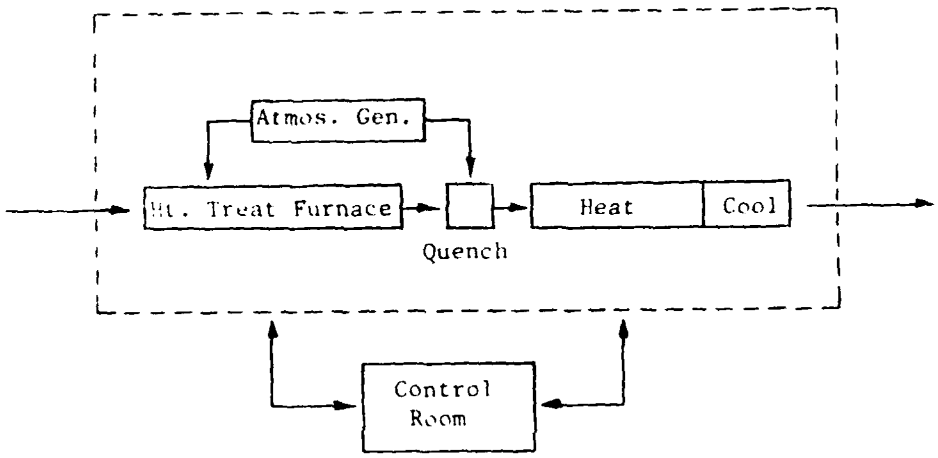
Of all the loss events which may occur and which are within reasonable scope of control through equipment specifications, only the explosion/fire event would be likely to cause complete loss of equipment. Cost to replace a rotary hearth furnace with controlled atmosphere could be $1,000,000 and require 18 months.

Preventative actions would be equipment specifications which include compliance with mandatory standards at federal, state and local levels and conformance to recognized standards such as Underwriters Laboratories, Inc. (UL), Factory Mutual (FM), American Society for Testing and Materials (ASTM), National Fire Protection Association (NFPA), National Electrical Manufacturers Association (NEMA), Joint Industry Council (JIC), etc. In addition, the installation specifications should require conformance to these standards and the manufacturer's installation drawings. The actual installation should be inspected by a qualified engineer for verification purposes.

Operator error, Event #7 in the block level analysis, is a factor which under certain circumstances could result in major systems damage. Although operator error is outside the scope of equipment specifications, there are several ways in which it may be influenced from a design approach. The first technique would be to design the equipment so that no operator involvement is required. This, of course, makes the equipment more complex, increases the cost and introduces the possibility of additional failure modes because of additional components in the control loops. A second technique is to design the equipment so that operator error is prevented through suitable interlocks. This usually does not add as much to the cost as completely eliminating the operator since most automatic equipment must have provision for a manual mode for maintenance and set-up purposes and this cost is present in any case. The net result of technique #2 is that the operator is still present in the control loop but he is prevented from making major mistakes through control circuitry.

A non-design oriented approach to prevention of operator error is via operator training. This approach may be fostered through contractual specifications which require the equipment manufacture to provide a complete operator's manual, a training session of suitable length, and revisions to the operator's manual to reflect field modifications of the equipment.

Heat Treat Furnace



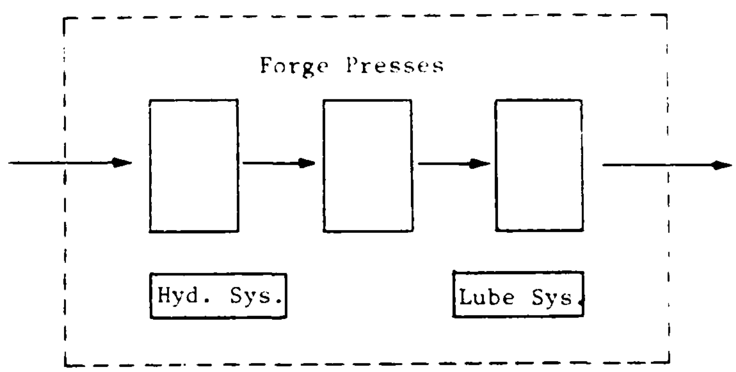
Block Level Events which may cause failure or loss of function:

1. Loss of electrical power
2. Loss of fuel supply
3. Loss of cooling water
4. Internal mechanical failure
5. Loading/unloading mechanism
6. Explosion/fire
7. Loss of control
8. Act of God
9. Operator error
10. Sabotage, war-bomb, missile, etc.

Event #6, Explosion/fire, is the only event which is apt to cause a complete loss of equipment. Cost to replace a multi-zone roller hearth, heat treat furnace with oil quench tank could be $2,500,000 and require 18 months.

All of the comments relating to Rotary Hearth Furnace apply to this section. The system within the block is more complex since it includes an oil quench bath, atmosphere generator, cooling and agitation of quench oil, and another furnace. This greater complexity gives rise to more risk elements (failure modes). These elements are within the block and the major external elements which may cause failure remain the same.

Forge Press Line



Block Level Events which may cause failure or loss of function:

1. Loss of electrical power
2. Loss of compressed air
3. Loss of cooling water
4. Internal mechanical failure
5. Failure of loading/unloading devices
6. Fire

7. Operator error
8. Set-up error
9. Act of God
10. Sabotage, war, etc.

The block level event which is most likely to cause severe loss is fire. Even with fire, the probability of complete loss is rather remote. However, if replacement were necessary, the cost could exceed $1,000,000 (per press), and require 18 to 24 months for replacement. From the standpoint of equipment specifications, the most positive action would be to require use of a fire-resistant hydraulic fluid in all hydraulic presses. (Three of the plants visited use conventional fluid.) Another possibility is to use a mechanical press instead of a hydraulic press where the application permits. Although they are outside the scope of equipment specifications, several secondary measures also would be quite beneficial: (1) develop nonflammable lubricants for the punches and dies; (2) require frequent cleaning of the presses, overhead, and exhaust systems; and (3) require suitable fire protection systems for the forge press area.

Another area for investigation in a forge press line is the automatic loading mechanisms. The type of device employed in the plants ranges from human through mechanical to robotic. Because the devices must load and unload projectiles from the press tooling, they are in the pinch point area and failure of interlocks can cause broken tooling and damaged presses. It is important therefore to analyze the effect of block level events on the loading/unloading mechanisms which are, in fact, a part of the press system.

DISCUSSION

In this section, the topics covered will address the major items noted during the plant visitations.

Furnaces, Ovens and Atmosphere Generators

In all the plants, heating equipment is a key part of the manufacturing process. The necessity for heating is not likely to change to any great extent since it is employed in several separate operations. The need to heat mults prior to forging is based on reducing the strength of the steel to effect a reduction in the pressure required to form a projectile. This allows use of a smaller press and permits some economy in tooling. Another use of heating comes prior to nosing and for the same general purpose as that prior to forging. A third, generally used, heating cycle is required to develop the mechanical strength properties required for most projectiles. This heating process incorporates a heating, quenching and tempering cycle which actually requires two separate heating cycles. Any or all of the heating cycles may use special atmospheres to retard or avoid oxidation.

Types of equipment employed in the plants for these heating operations include roller hearth furnaces, rotary hearth furnaces, salt baths, box furnaces and induction heating units. In consideration of future installations, the most desirable type of equipment from the safety standpoint would be induction or electric resistance heating. The advantages include a rapid heating cycle which reduces or eliminates the need for special atmospheres, the smaller physical size reduces floor space requirements, there is no explosion or fire hazard and there is a minimum of maintenance required. Equipment startup is instantaneous and this eliminates the long off-shift and weekend idling periods which are normal for most high temperature furnaces. The less than desirable hot environment caused by large furnaces is not present with induction heating, and failure of electrical power does not cause a hazard as it may in furnaces. However, water cooling is required and this creates a potential failure mode if water flow is interrupted. As a final argument for induction heating, changes in the cost and availability of fuel have altered the economics so that the total cost of this equipment may be quite competitive with furnaces. There is no denying that a powerful argument for furnaces is their flexibility in handling different sizes and shapes.

Existing furnaces, both gas and oil fired do represent a source of potential hazard from fire and explosion. The magnitude of the risk depends on many factors, but the means to minimize the risk depends on installation of devices such as fuel safety shutoff valves, fuel and air supervisory switches, timers and combustion safeguards with interlocks. Given a proper installation with the proper equipment, the remaining and vital requirements are training of operators, maintenance of equipment, and location in the plant.

In order to assure the inclusion of proper safety devices, all gas or oil fired furnace specifications should include "must meet commercial insurance underwriters' standards and recommendations set forth in their data sheets on process furnaces." The same inclusion should be made in the specifications for special atmosphere generators such as exothermic, endothermic, and nitrogen generators. Further applicable standards are National Fire Protection Association (NFPA) No. 86B, "Industrial Furnaces," and No. 86C, "Industrial Furnaces Using a Special Processing Atmosphere."

In private industry, an insurance underwriter will hold periodic inspections of a plant aimed at reducing the risk exposure from fire. Furnaces and ovens are prime areas for surveillance, and inspection often results in requests to plant management to modify or improve equipment, maintenance, operating practices and fire protection devices to reduce the risk (and maintain reasonable premiums). Because the Federal Government is self-insuring, there is no equivalent direct influence. This is especially true in plants in which both buildings and equipment are government owned. In this case, the contractor will usually only carry insurance to cover loss of production. In COCO plants, the insurance carried by the contractor will cover both the buildings and production loss but not equipment since that is government owned. Whichever the case may be, there is no entity with equivalent influence actually inspecting the as-installed condition. Despite this fact, equipment specifications should require the furnace builder to construct the equipment to recognized standards.

Other required items in specifications for process furnaces should be formal contractural obligations for the builder to provide complete, documented, operating instructions and training for the operator(s). The increasingly complex nature of some heating equipment (especially continuous, integrated, heat, quench and draw facilities) demands a highly qualified, well trained individual. Because of illness, vacations, turnover, etc., the contractor should be required to have at least one more employee trained as an operator. This will dictate that the contractor provide a minimum of two employees for training by the vendor. Since installation and start-up often cause or require modifications to systems, the contract should require that the vendor supply an updated safe operating procedure manual after acceptance or prove-out.

Forge Presses

All of the plants use large presses to form pieces of bar stock to the approximate shape required by the projectile being made. This is done to minimize the amount of metal which must be removed by machining. Until a more economical or better way to make the basic shape is found, the large presses will continue to perform this function.

The typical forging operation found in the metal parts plants utilizes a hot work piece which is moved from operation to operation either within one press or from press to press or a combination of both. The tooling is usually designed so that the work piece drops into the pit area on completion of the last operation. The shaped projectile is conveyed from the pit to the next operation. Movement within the forging operation is accomplished by human, mechanical or robotic means. The workpiece, commonly referred to as a mult, is a piece of steel bar stock weighing from approximately 3.1 pounds for a 60 mm projectile up to 240 pounds for an 8-inch projective, and heated to a temperature of approximately 2200°F. The tooling is lubricated by liberal application of a fluid containing graphite. Application may be by either manual or automatic means. The tooling is cooled by water circulating through internal passages and in some cases the water is also applied externally.

The forging operation produces smoke and flame primarily because of contact of the hot mult with the graphite and oil die lubricant. The smoke is drawn upward and collected in ducts which exhaust it from the building. However, a residue of the lubricant condenses on the presses and in the ducts. Since this material is flammable, it presents a fire hazard. Consequently, a forge line requires periodic shutdown for clean-up and maintenance.

Most of the presses used in the plants are hydraulic and require an operating fluid. A typical press line uses a central system which contains 5,000 to 10,000 gallons of fluid. Other components of the hydraulic system are high pressure pumps, circulating pumps, accumulators, reservoirs, filters, valves, cylinders and heat exchangers for cooling. If the fluid in the system is conventional hydraulic oil, there is significant potential for fire because the hot mult is a ready source of ignition. Leaks and ruptures are a common failure mode for hydraulic systems.

All of the plants using forging lines have provided sprinkler systems for fire protection. The pit level of the presses, which contains dripping water and lubricant, is protected by sprinkler heads, as are the floor and crown levels. The exhaust ducts have internal sprinkler heads. Therefore, the protection from fires has been provided by secondary means. The survey team also found that three of the six plants were exclusively using fire resistant hydraulic fluid and two of the six were using a fire resistant lubricant for the tooling. Use of this lubricant avoided the flame and greatly reduced the smoke so that emissions from these plants were significantly abated. These measures for primary avoidance of fires are highly desirable.

There is no question that presses fail from causes other than those that either result in or result from fire. Some of the especially serious failures from a cost-and-repair-time standpoint are those that result in damage to the frame, tie rods or crankshaft (mechanical presses). These failures are almost always induced by overloads resulting from double hits. It is standard practice to have safety interlocks on the tooling to insure ejection of a part prior to loading the next one. However, a redundant safety device which gives additional assurance against overloads is a good investment. This should be a device of the type which stops the ram when excessive stresses are sensed in the frame or other key component.

Equipment Selection and Specification

Most of the equipment used in the metal parts manufacturing plants which were surveyed is of a basic design which has been in existance for some years. Manufacturers have been led by field experience to improve designs so as to minimize failures and promote reliability. Consequently, the basic machines should present a minimum of trouble if operated within design parameters. The auxiliary systems, such as controls, lubrication, hydraulics, loading systems, chip conveyors and cooling medium do vary from installation (application) to installation and may have a higher failure rate. Furthermore, these systems give a manufacturer some latitude to modify price to complete with others. Because of this, the area of peripherals deserves careful consideration.

There are several general approaches to equipment specification which may be considered in order to further minimize failures and reduce associated hazards. One approach would be to require the builder to make a complete failure mode or fault tree analysis of the systems, sub systems, and components in his equipment and make any changes necessary to minimize failures and to assure safety if failure should occur. This approach could be characterized as an attempt to attain the utmost in safety and reliability.

A second approach would be to require the same analysis but only document the corrective actions and their associated cost. This would allow the government and/or its agent to decide if the cost to eliminate or control a design deficiency outweighed the magnitude of the potential hazard.

A third and possibly more desirable approach to equipment specification from a cost/benefits viewpoint is to rely on the builder's expertise and experience in the design and construction of his standard products as the fundamental ingredient in assuring a basically sound piece of equipment. In order to help insure a functionally capable piece of equipment, it is necessary to specify compliance with government regulations (all levels) and general industrial standards such as Occupational Safety and Health Act (OSHA), American National Standards Institute (ANSI), National Electrical Manufacturers Association (NEMA), Joint Industry Council (JIC), Underwriters' Laboratories, Inc. (UL), and others. It sometimes goes unrecognized that these regulations and standards have been developed for the purpose of promoting safety and reliability.

In cases where several pieces of equipment are to function as a system, the reliability of the controls used with the basic equipment may be of prime concern. This may require the use of logic diagrams to define the operating strategy of the pieces of equipment to be interfaced. Two examples of possible applications would be the interlocking of a forge press line with its material handling system and the coordination of a heat treat furnace, quench tank and tempering furnace. The equipment builder's control engineers can interpret the logic diagrams and develop suitable control schemes.

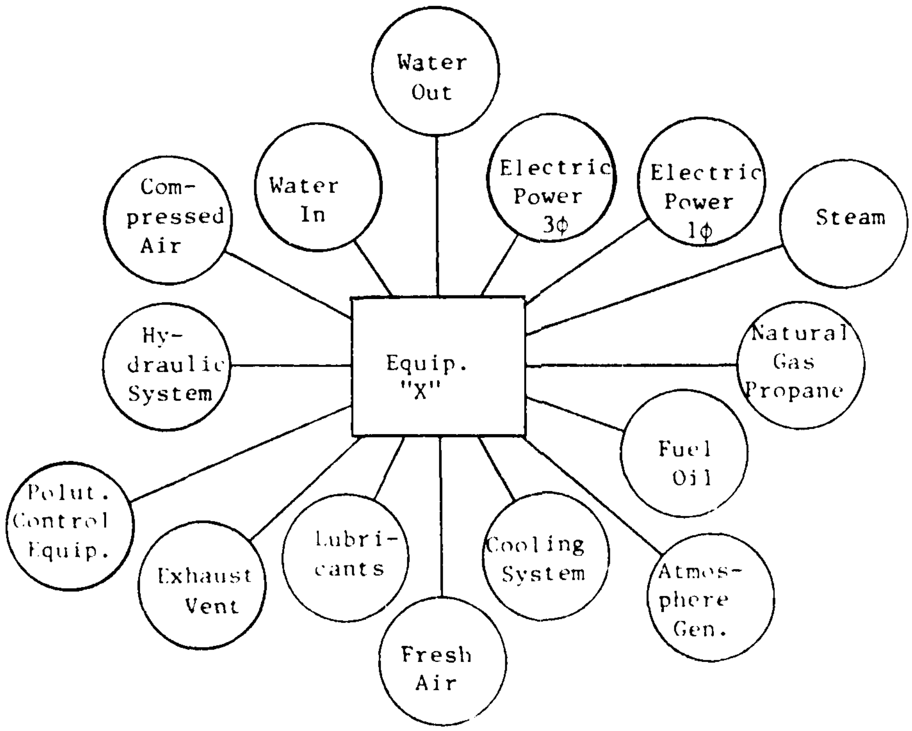
After several equipment manufacturers have responded to requests for quotation, there is a need to make a selection. In many cases, this will be made on price or someone's preferences. A selection concept which has been used to good advantage is that of life cycle costing. This method recognizes criteria in addition to initial cost so that the basis for selection may include expected life, maintenance costs, production costs, installation costs, etc. Determination of these factors is of necessity based on judgement which in turn is based on past experience. In this area, ARRADCOM is at a disadvantage because it has no direct access to records of equipment failures and maintenance costs. Without this reliability input, the ability to select (and specify) equipment is eroded. Some private firms record maintenance parts usage which allows them to identify premature failure of controls, poor overall equipment performance, excessive downtime, and high maintenance costs.

This knowledge assists them in making specifications and in selecting equipment.

AS INSTALLED - FAIL SAFE ANALYSIS PROCEDURE

Purpose

The purpose of this procedure is to assure the safety of equipment when it is installed and operating in a plant. The need for this analysis occurs because a piece of complex equipment may have many interfaces with plant systems and, although the equipment may be standard, each installation has its own unique environment. The information which is to be obtained is the impact of failure of the plant systems and surrounding equipment on the piece of equipment under consideration. The sketch below illustrates some of the possible interface elements.



The analysis should be performed on major pieces of critical equipment which have a high cost and an inherent possibility of failure. Forging presses and heating equipment used in production processes are examples. The term "critical equipment" is used here in the context that its failure will totally (or severely) disrupt the productive capability.

Procedure for interfaced plant services analysis

1. Determine all external services required by the piece of equipment such as those indicated above.

2. Perform a block level (system level) failure mode analysis by establishing the result of a temporary or extended interruption of each of the external services.

3. Extend this analysis by consideration of the effect of an abnormal level of each of the services.

Procedure for environmental analysis

1. Determine all the interfaced equipment

2. Determine all the adjacent equipment

3. Perform a block level failure mode analysis by establishing the effect of:

   (a) Failure of interfacing equipment to perform its function.

   (b) Failure of adjacent equipment.

   (c) A fire in the immediate area.

   (d) Building roof failure resulting in overhead water leaks.

   (e) Building drain failure resulting in a flood .

   (f) Such other environmental elements as may apply.

CONCLUSIONS

Typicality of Plants to High Volume Private Facilities

The plants visited are typical metal working and machining facilities which employ equipment commonly found in the private sector of industry. Because of this, the risks, hazards, and operating problems are of the same general nature as those found in similar plants in private industry. Despite the many similarities, there are several significant differences which may adversely affect equipment safety. These are: (1) the intermittent scheduling of production according to procurement needs, (2) the purchase and installation of equipment which may not receive much use, or at best be used periodically, and (3) the fact that the government owns and insures all of the equipment and some of the plants. These factors do not change the nature of any hazard but they may affect the probability that an undesired event may occur.

Although there are many possible failure modes of the plant equipment, the result of the failures which was judged to be the most likely to cause extensive damage was fire. Consequently, the most obvious secondary measure to control loss would be suitable fire protection devices. All of the plants surveyed had such equipment and had procedures for periodic inspection of those fire protection devices.

Heating and Forging Equipment

From the standpoint of the potential hazard of fire and the high capital cost of the equipment involved, attention should be focused on equipment used in heating for forging, forging, and heat treating. The equipment used in other operations such as turning, boring, slotting, welding, and threading has a lower replacement cost if total loss should occur, the replacement time is shorter and in most cases failure of these pieces would have a lesser effect on productive capacity. Other areas such as painting are hazardous but, in general, the survey showed that measures have been taken to reduce and control loss exposure in these facilities.

Training Procedures

The safety of operating personnel and equipment cannot be assured unless the following are provided:

1. A complete instruction manual covering step-by-step operation of the equipment. The manual must be updated whenever modification of the equipment or operating procedures are made.

2. Operator training by knowledgeable and qualified personnel in the proper operating procedures using the step-by-step manual.

These requirements are especially critical because of the practice of periodic procurement which activates the plant for a period and then puts it in layaway for a period. Turnover of personnel plus normal human failure to retain unused information or knowledge can contribute to personnel injuries and equipment failures resulting from errors in operating procedure.

RECOMMENDATIONS

The Munitions Production Base Modernization and Expansion Program places the metal parts contractor in a position to exert some influence over the selection of both equipment and vendor. There are good reasons for this situation to exist. It is obvious that the metal parts contractor exerts the major influence over equipment after it is installed in the plant which he operates. The useful life, reliability and productivity of the equipment will be influenced not only by its design, but also by its installation, maintenance and operating conditions. The ever increasing cost of equipment and the corresponding cost to repair or replace it in case of failure demand that close attention be paid to all factors which influence its life. The recommendations contained in this section address these factors.

Hydraulic Systems

All hydraulic systems used in equipment in the plants should use a fire resistant hydraulic fluid such as phosphate ester. All system components must be designed to operate with the chosen fluid. A permissable modification to the above would be to allow exclusion of those systems containing small quantities of fluid provided that they are located in areas in which they are not exposed to sources of ignition. A typical example would be lathes located away from ignition sources and equipped with hydraulic devices.

Gas and Oil Fired Equipment

All gas (natural and synthetic) and oil fired heating equipment such as rotary hearth, roller hearth, and other furnaces are primary ignition sources which should be given special attention. Atmosphere generators which make combustible gases (such as exogas and endogas) are often used with the furnaces. Specifications for all of these devices should include a requirement to use controls, design, and installation recommendations provided by commercial insurance underwriters.

Exposure Factors

Because of the realities of the operating environment of some equipment, the added cost of specifying weatherproof electrical systems, fluid reservoirs, motors, etc., should be evaluated. This requirement is based on prevention of damage to equipment from: (1) water dripping on it or running over it from roof leaks or sprinkler systems actuation and (2) steam or solvent cleaning. It was observed in one plant that water runs over some equipment when it rains due to leaks in the roof. In one case this led to failure of electrical distribution equipment.

Emergency Power

Provision of an emergency power source for some equipment is recommended. Certain types of equipment such as roller hearth furnaces and rotary hearth furnaces with atmospheres may be seriously damaged by the unplanned interruption of electrical power. A power failure immobilizes the rolls in a roller hearth furnace and the combination of weight (projectiles) and temperature may cause the rolls to warp and thus render the furnace unusable. Rotary hearth furnaces utilizing an atmosphere may employ a fluid seal which is maintained by a pump. A power failure may cause the pump to shut down and residual heat may then cause seal components to be warped.

Propane Storage

The requirement to use standby fuel sources is increasing. All propane vaporizing systems should be updated to the latest technology so that safety is assured. Several sets of standards exist, but it is suggested that the latest commercial insurance underwriters' guidelines should be followed. The Compressed Gas Association also has developed data which may be useful.

Die Lubricant

The use of flammable die lubricants in the forging operations provides a source of combustible material which actually burns during normal press cycling. Although some effort has been made to develop a nonflammable lubricant, only several plants use one. Development of a suitable nonflammable lubricant should continue in order to reduce the risk of fire in the press area and to avoid air pollution.

Training/Safe Operating Procedures

All major equipment purchases should contain a formal provision for training of operating personnel in safe operating procedures. Documentation of these procedures should be available for the start up training period. Although this recommendation is good policy in general, in the case of the metal parts plants it could be limited to complex equipment requiring more than on-off operation. Cognizance is given here to the philosophy that in order to incorporate training requirements in the purchase contract some thought must be given as to: (1) what training is required, (2) where it should be done, (3) who should receive it, and (4) how long it will require.

Provision must be made to update the procedures to include field changes made during installation, debugging and prove out. The procedures should be reviewed for accuracy by the appropriate personnel - including the operator(s).

Several plants surveyed are following a procedure similar to this at present.

Installations and Modifications

Both original installations and modifications of equipment should be done in accordance with factory drawings in such a manner as to comply with commercial insurance underwriters and Joint Industry Conference (J.I.C.) standards, as well as any local code requirements. Some commercial insurance underwriters provide factory risk consulting services (app B).

Only qualified skilled trades persons should be used for the installation of equipment. This recommendation is based on the need to translate well designed plans into the actual installation. The same objective could be accomplished by using lesser skilled trades persons under the direct supervision of an engineer. The danger in this approach is that the engineer may be unavailable for some time periods and may not detect sub-standard work done during his absence.

Field inspection by qualified personnel should be used to verify that the installation and modification of equipment comply with all applicable requirements.

Plant Layout

The location of equipment in the plant should be done to a layout which not only optimizes space requirements and material flow, but which also considers survivability of the production capability in case of fire, failure of conveyor systems, etc. There is also a need to consider the space envelope required around each piece of equipment for maintenance and repair.

Failure Mode Analysis - Installation

Should require an abbreviated failure mode analysis dealing only with installation oriented factors. As in the other recommendations, this requirement should apply to the major systems such as furnaces and forging presses since these are the high cost areas.

Personnel

For the new complex equipment, operator training is necessary and should be a part of the purchase contract. However, it is equally important to select personnel who possess such qualifications as reliability, good attendance, and the ability and desire to learn.

The importance and complexity of the operator's job may require that a qualified person be present at all times. For these jobs, trained back-up personnel must be available in case of illness, vacations and employee turnover.

There were indications that at some plants personnel were performing tasks for which they were not fully qualified and that training for jobs was not thorough.

Equipment Maintenance

All critical equipment should have a maintenance schedule which is enforced by a reporting document. Spot checks should be made as further corroboration that the work is actually done.

Performance specifications usually make the equipment builder fully aware of the application of the equipment and this puts him in the best position to make a maintenance schedule. He knows both the construction and application of the equipment he builds. For this reason, maintenance schedules for equipment should be required in the purchase contract. These should be modified to reflect actual operating conditions in the plant when the environment changes from that used as base in the original formulation of the schedules.

Only qualified personnel should be used to perform maintenance on critical equipment. These personnel should have passed formalized proficiency tests in their trades and should also have received training on the specific equipment which they service.

Equipment maintenance schedules are common practice; however, enforcement and documentation of maintenance may sometimes not be entirely adequate.

Safety Officer

The resident safety officer should look at and be responsible for equipment safety as well as personnel safety. In the normally accepted context, the word "safety" refers to personnel safety . Consequently, the plant safety officer normally engages in accident prevention activities in all aspects of plant operations, including equipment. The extent of his involvement with equipment is usually limited to consideration of proper guarding, safe operating procedure, location of controls, posting of warning signs, etc. Broadening the scope of the job to include equipment safety would impose the need for a more extensive technical background in the electrical and mechanical areas. A competent safety officer with technical expertise could be responsible for the failure mode analysis suggested above.

Equipment Performance

Where multiple similar pieces of equipment are being procured for a production line, the plant acceptance should be based on extensive testing on one of the pieces of equipment rather than a smaller production run on each machine. If a potential problem exists, it is now more likely to be uncovered. Any machine deficiencies which are revealed may be corrected within the warranty period and the same corrections applied to the other machines. Requirements for tooling changes may also be revealed in this manner more easily and the same changes made for the other machines.

Fire Protection

All production equipment should be protected by full sprinkler system coverage.

Equipment Specifications

Specifications for the heating, forging, and heat treating equipment should be modified to include several factors which are not uniformly used in all the plants. These factors are the fluids used in hydraulic presses and the safety features required for gas or oil fired heating equipment.

Equipment Design

Equipment should be designed so that operator error is prevented through suitable interlocks. This usually does not add as much to the cost as completely eliminating the operator since most automatic equipment must have provision for a manual mode for maintenance and set-up purposes and this cost is present in any case. The net result is that the operator is still present in the control loop but is prevented from making major mistakes through control circuitry.

Forge Press Area

The following measures should be pursued to enhance fire protection in the forge area: (1) require frequent cleaning of the presses, overhead, and exhaust systems and (2) require suitable fire protection systems for the forge press area.

Equipment Inspection

In addition to requiring furnace builders to construct equipment to recognized standards, there should be an inspection of the equipment in the as-installed condition which should be equivalent to the inspection required by insurance underwriters if the equipment were installed in a private sector plant.

Press Interlocks

It is standard practice to have safety interlocks on the tooling to insure ejection of a part prior to loading the next one. However, a redundant safety device which gives additional assurance against overloads is a good investment. This should be a device of the type which stops the ram when excessive stresses are sensed in the frame or other key component.

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APPENDIX A. HAZARD QUESTIONNAIRE

A hazard questionnaire was given to each plant. The questionnaire, responses, etc., are discussed below.

Hazard Questionnaire

1. What events have occurred in your plant that have resulted in loss of production or endangered personnel due to, or related to, unexpected production equipment failure?
2. What would you anticipate could become a safety problem related to plant or production equipment?
3. What outside regulatory agencies or companies monitor the safety factors related to production equipment?
4. Do you have a fire protection program with a local fire company?
5. What chemicals or cleaning fluids are used to maintain the production equipment in your plant?
6. What training programs have you established for your personnel who operate and maintain production equipment?
7. Do you have a problem meeting OSHA standards with installed equipment which met OSHA standards prior to installation?
8. What would you add to existing production equipment specifications which would tend to reduce the possibility of accidents?
9. Are design and functional modifications to equipment considered from a safety standpoint prior to implementation?
10. What formalized fire protection plans do you have?

Responses to the Hazard Questionnaire

The responses to the Hazard Questionnaire were analyzed, and the extracted information was used as appropriate throughout this report.

A brief synopsis of the responses is given below.

1. Serious, potentially hazardous events occurring in the plants ranged from none to several with significant losses (both in production and cost).

2. Most plants indicated that they had taken measures to control all potential safety problems which they could foresee. However, several plants noted items which were under study for correction.

3. The outside regulatory agencies which monitor the plants varied quite widely and ranged in number from two to eleven.

4. All plants have a fire protection program with a local fire company.

5. All plants noted several cleaning fluids used to clean production equipment. The fluids ranged from non-flammable to highly flammable with low flash point. The decomposition products of some of the fluids are toxic.

6. The training programs for maintenance personnel ranged from none (formal) to regular classroom sessions. All plants used on-the-job training.

7. No plants had a problem meeting OSHA standards with equipment which met OSHA standards prior to installation.

8. The concensus of all plants was that current equipment specifications included all pertinent standards which would be beneficial towards reduction of accidents.

9. All plants required consideration of all proposed equipment modifications from a safety standpoint prior to implementation.

10. All plants had formalized fire protection plans.

Observation Guide for Hazards Analysis

The following questions formed the guide used in assessing the potential hazards in the plants which were surveyed.

1. Determine items which cross the boundary as input to or output from the plant, such as electrical power, potable water, process and expense materials, product, waste streams and effluents.

2. Determine what failure modes could be involved with these items which could cause serious personnel injury, property damage, or loss of production.

3. Obtain (or make) process flow diagrams and plant layout plans.

4. Look for failure modes of process equipment such as that associated with heating, cooling, painting and chemical treating. Consider the effect of a power and/or fuel interruption on this equipment.

5. Consider the effect of a power failure on the fire protection system.

6. Are all pipes identified as to their contents such as water, compressed air, natural gas, waste, compressed gas, etc.? Could a mix up occur?

7. Are all valves identified as to their purpose? Are warning legends posted?

8. Are all electrical switches identified as to function?

9. Are safety and operating control set points identified on gauges, valves, etc.? Are control diagrams and sequences of operation available in the factory?

10. Do local electricians have to qualify for their jobs? What training is required? Are National Electrical Code standards followed?

11. Do local pipe fitters have to qualify for their jobs? What training is required?

12. Are bulk storage tanks for flammable materials located a safe distance from the plant? Are dikes sound?

13. Is there a formal system to deal with bomb threats? Does it include elements of risk management?

14. In the safety area:

    a. Is there a safety engineer (officer) at the plant?

    b. Is he a government or contractor employee?

    c. Is there evidence of a safety program?

    d. Is there a supervisors safety manual?

    e. Is there an emergency medical team?

15. In the fire protection area:

    a. Is there a local fire marshall?

    b. Who services sprinklers, extinguishers, etc.?

    c. Is there a trained fire brigade?

    d. Is there a direct fire alarm connection to a municipal fire station?

    e. Are building exits identified with lighted signs?

    f. Are escape provisions adequate?

    g. Does the plant have insurance with a fire underwriter?

    h. How frequent are his inspections?

    i. What is insured against loss?

    j. Is there adequate fire protection in the painting area?

k. Is storage of flammables minimal on the shop floor?

Operating Practices

Recognition that daily plant operations have a significant impact on safety and hazard control led to identification of the need to measure performance in this area. Because operations have a broad scope, their measurement is somewhat complex and it is difficult to obtain meaningful results in absolute terms. Analysis of factors which affect the safety of equipment was concentrated in fourteen areas which were studied. These areas are:

- Housekeeping
- Material Handling
- Storage
- Work Habits
- Special Processes
- Manufacturing Information
- Identification of Material
- Fire Prevention
- Feedback Systems and Corrective Action
- Preventative Maintenance
- Safety
- Training
- Machine Utilization
- Plant Layout

Furthermore, an effort should be made to insure measurement in a manner which relates to the need for effective ongoing programs rather than simple, one-shot, drives. Accordingly, the following list covers the basic information required in each area.

- Is there recognition of need for control?
- Is there a formal program of control?
- Is the basic program adequate?
- Who is responsible for control?
- Is the program functioning?
- Is there visibility of the success of the program?
- Is there a periodic audit to assure the program is followed?
- Is there a plan for analysis that will keep the plan up to date to meet new demands?

Application of this thought process to the previously identified areas resulted in the Operating Practices Checklist. [illegible] list provides for a simple yes-or-no answer to an array of questions which bracket fourteen performance areas. Rating of a plant [illegible] of the checklist would be judgemental in nature, but it [illegible] that a majority of "yes" answers indicates that the plant [illegible] has established, and is following, practices which [illegible] secure operation. Ideally all questions should have a positive response. The plants surveyed for this study were not rated [illegible] checklist because of the time element. The checklist was used [illegible] to assist in recognition of possibly hazardous conditions and practices.

Operating Practices Checklist

Housekeeping

1. Are enough trash containers located throughout the facility to accommodate the needs?

2. Are tools, work stations, machines and equipment kept clean to minimize the possibility of [illegible]

3. Is emphasis placed on preventing oil leakage from facilities and equipment onto materials and floors?

4. Are there periodic formal housekeeping inspections?

Material Handling

1. Is the responsibility for control and use of handling equipment specified and understood?

2. Are the stops, brakes, rails and [illegible] on [illegible] conveyors [illegible]

3. Are there formal programs for the training and certification of trucks and truck drivers?

4. Is there a clear responsibility and [illegible] maintenance of handling equipment?

Storage

1. Is the responsibility for maintaining storerooms clearly defined?

2. Is the space allotted for storage enough to accommodate an orderly arrangement of material in its proper storeroom?

3. Is all material in the storage areas identified properly and hazardous materials confined to special designated areas?

Work habits

1. Are the guidelines for work habits clearly defined?

2. Have the work habit guidelines been communicated to all employees?

3. Are operators conscious of avoiding the use of dirty, contaminated or damaged materials?

4. Are the responsibilities for enforcing good work habits understood?

5. In general, do the work habits reflect the care that is necessary in preventing damage and contamination?

6. Are there spelled out precautions with tools and equipment to prevent failure and damage?

Special Processes

1. Is the correct information - specifications, information sheets, drawings, instructions - available in the shop and up to date?

2. Is the equipment capable of meeting the process requirements?

3. Is there visibility that the processes are in control - charts, check sheets, sample parts, reports, etc.?

4. Do the inspection and test procedures give evidence the process is functioning properly?

5. Are there formal programs for the repair and calibration of the equipment and instruments?

6. Are there programs for training and certification of operators?

Manufacturing Information

1. Is there a formal system for control of manufacturing information with specific assignments of responsibility?

2. If properly followed, will the system insure that the latest information is available at the manufacturing location?

3. Does the system provide controls for all types of manufacturing information - drawings, process specifications, instructions, test specifications, change notices, etc.?

4. Will the system insure the removal of old subs and obsolete information?

5. Are there up-to-date process specifications for all the process type operations available to manufacturing.

6. Are operator, inspector, and tester instructions available and up to date?

7. Are the steps for control of manufacturing information spelled out to all persons who have responsibility in control and use of it?

8. Are periodic audits conducted to assure all aspects of the system are being followed?

Identification of Material

1. Is all material on the receiving floor identified by type, inspection approval and routing?

2. Are all parts and materials in storerooms identified?

3. Are partial containers of material and parts identified?

Fire Prevention

1. Is there an adequate system in place for control of fires? (sprinklers, dry chemical, fire extinguishers, etc.)

2. Is there a cadre of local personnel trained in fire control?

3. Is there a working relationship with a local fire company with direct alarms, etc.?

Feedback Systems and Corrective Action

1. Is there feedback to management of the accomplishments, problems and conditions in manufacturing?

2. Are there formal notifications of defective material and test failures?

3. Are there charts and reports to show manufacturing performance, problems, and trends?

4. Are all the manufacturing feedback procedures documented?

5. Is there a formal corrective action program that provides regular attention, follow-up, and corrective action?

Preventative Maintenance

1. Is there an active preventative maintenance program for manufacturing equipment?

2. Is there a documented schedule showing frequency and extent of preventative maintenance actions?

3. Are records maintained to substantiate that preventative maintenance was performed?

4. Are critical safety items included in the preventative maintenance program?

5. Are the safety items marked to show that the preventative maintenance was done?

6. Is an analysis of normal maintenance problems made to determine inputs to the preventative program?

7. Are preventative maintenance schedules and reports made visible to management?

8. Are periodic audits performed to assure the program is being effectively followed?

Safety

1. Are the responsibilities for safety clearly defined?

2. Are safety requirements communicated to all employes?

3. Is there safety training for new employes?

4. Are safety warnings visible - no smoking, aisle markings, stop signs, electrical warnings?

5. Are safety practices - such as wearing safety equipment understood?

6. Are the safety practices strictly enforced?

7. Are all employes involved in safety efforts - safety observer program, safety suggestion system, etc.?

8. Is there a formalized procedure for reporting accidents?

9. Is emergency safety equipment available throughout the facility - first aid, stretchers, emergency instructions, etc.?

10. Are persons with defined safety or emergency responsibility available at all times?

11. Are regular safety inspections performed?

12. Are new equipment, methods, and products evaluated and approved from a safety standpoint?

Training

1. Is there a central responsibility for manufacturing training?

2. Are there specific training programs for the more specialized jobs:

   welders?
   testers?
   tool and die?
   special machine operators?
   special process operators?
   maintenance?
   technicians?
   inspectors?
   etc.?

3. Are there training efforts for routine jobs other than working with experienced operators?

4. Has a time schedule been established for training for each job?

5. Are people formally evaluated during the training cycle to assure satisfactory progress?

6. Are training manuals and instructions prepared and available for new equipment and processes?

7. Is there follow-up training to review and up date people on new things?

8. Are training programs for the more skillful jobs co-ordinated with outside educational institutions?

9. Are there formal training activities for the manufacturing management people?

10. Are there specific programs or efforts directed toward operator involvement and attitude?

11. Are there specific efforts toward communication to all employes - newsletters, meetings, etc.?

Machine Utilization

1. How many machines in the plant are over 10 years old and/or, are obsolescent?

2. Is there a master plan to provide for replacement of badly worn, over age or obsolete equipment?

3. Which machines are down for maintenance more than 10 of the maximum possible productive time?

4. Is there a well organized preventive maintenance program including provision for a stock of critical spare parts?

5. Are there some specific problems that prevent timely replacement of inefficient equipment?

6. Which machines in the plant have the lowest chip cutting time as a percentage of machine hours scheduled?

7. What is the turnover rate of machine operators?

8. Are machine operators suitably qualified?

Plant Layout

1. Have support facilities, service facilities and special areas been properly allocated in the overall layout concept?

2. Is the layout suited to the building structure?

APPENDIX B. COMPANIES WITH FACTORY RISK CONSULTING SERVICES

American Insurance Association
Engineering and Safety Services
85 John Street
New York, NY 10038
212-433-4400

Alliance of American Insurers
29 North Wacker Drive
Chicago, IL 60606
312-558-3700

Factory Mutual Engineering Association
1151 Boston-Providence Turnpike
PO Box 688
Norwood, MA 02062
617-762-4300

Industrial Risk Insurers
85 Woodland Street
Hartford, CN 06102
203-525-2601

Insurance Company of North America
Special Risk Facility
IVB Building - 27th Floor
1700 Market Street
Philadelphia, PA 19103
215-241-2660

National Loss Control Service Corp.
(Div. of Kemper)
Long Grove, IL 60049
312-540-2400

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Analysis Activity
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